UNITED STATES DEPARTMENT OF AGRICULTURE
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GERMINATION

Gross morphology and Evaluation of the Seedlings 1/

Essential Structures of the Seedling (figs. 1-3)

Radicle: The miniature root of the embryo before emergence from the seed coat.
Primary roots: (a) Tap root, arising from the base of the hypocotyl (b) Seminal, roots usually in pairs, arising from the cotyledonary plate at the top of the hypocotyl, as in Cereals.
Secondary roots: (a) Lateral, branch roots from the main or tap root. (b) Adventitious, arising from structures other than the root: Crown roots, arising from the first node. These remain underground and form the permanent root system in grasses. Brace roots, arising from nodes above the ground in grasses.
Cotyledons: The embryo leaves or seed leaves.
Primary leaves: The first true leaves.
Terminal bud: The growing point of the stem.
Axillary buds: The buds in the axils of cotyledons or leaves.
Hypocotyl: The portion between root and cotyledons, a transition zone between root and stem, the limits of which can be determined only by anatomical sections in many cases.
Epicotyl: The portion above the cotyledons, consisting of the primary leaves, the stem and terminal bud.
Coleoptile or sheath: A colorless leaf-like structure enclosing the first foliage leaf of a grass seedling.
Plumule (in grasses): The coleoptile and first foliage leaf.

Growth-habit of Seedlings

Epigeous: The hypocotyl elongates, carrying the cotyledons above the ground. Fig. 1.
Hypogeous: The hypocotyl does not elongate and, together with the cotyledons, remains underground. Figs. 2 and 3.

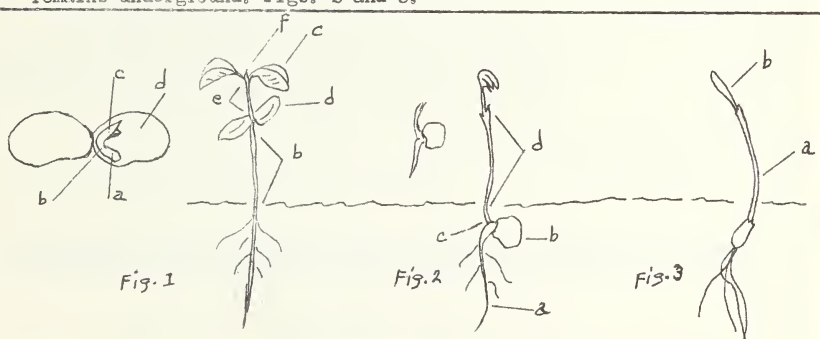

Fig. 1. Bean showing epigeous growth-habit. (a) Radicle; (b) hypocotyl; (c) primary leaves; (d) cotyledons; (e) epicotyl; (f) terminal bud.
Fig. 2. Vetch showing hypogeous growth-habit. (a) Primary root; (b) cotyledons; (c) hypocotyl; (d) epicotyl.
Fig. 3. Grass seedling. (a) Coleoptile or sheath; (b) foliage leaf.

1/ A few slight changes in wording have been made for purposes of clarification and are not intended to alter the original meaning as set forth in the Rules for Seed Testing.

Albina F. Musil, Seed Technologist. February, 1956.

Seedling Evaluation

COMPOSITAE - Composite or Sunflower Family (Manual pp. 113-119) 2/

Lettuce
(Manual p. 114, figs. 27-29) (Photo. neg. No. 19559-19560) 3/

Normal seedlings -

Root: Long, slender primary root with root hairs.

Hypocotyl: Long and vigorous with no deep splits.

Cotyledons: Two, may have some blackened or reddish areas, provided the seedling is vigorous and well-developed.

Epicotyl: Usually too small to be evaluated at the end of the 7-day test.

Infections: Slight infection by fungi, provided the essential seedling structures are well-developed.

Abnormal seedlings -

Root: None, short and weak, or stubby; usually associated with shortened hypocotyls.

Hypocotyl: (a) Short and weak, usually associated with short or weak roots.
(b) Malformed by severe twisting, granular areas, or deep splits.

Cotyledons: (a) Large blackened or reddish areas, usually along the midrib and associated with a short hypocotyl and root.
(b) A grayish cast over the entire area, usually darker at the midrib and associated with a short hypocotyl and root and with the seed coat remaining attached.

Infections: Decayed cotyledons.

Other Composites

Artichoke; Cardoon; Sunflower; Salsify; Chicory; Endive; Dandelion
(Refer to Manual, pp. 114 and 119, and fig. 30) 3/

2/ Manual for Testing Agricultural and Vegetable Seeds, U.S.D.A. Agric. Handbook No. 30.

3/ For complete list of negative Nos. of seedling photographs refer to A.O.S.A. Rules for Seed Testing, Table 2.

CRUCIFERAE - The Mustard Family (Manual pp. 119-124) 2/

Radish; Cabbage; Other Brassicas
(Manual pp. 120 and 124, figs. 31-33) (Photo neg. Nos. 2554, 19555, 19556)

Normal seedlings -

Root: Long, slender primary root with root hairs.

Hypocotyl: Long, or short but well-developed, with no deep splits or lesions.

Cotyledons: (a) One or two, with no decay at the point of attachment to the hypocotyl, and an intact terminal bud.
(b) Two, with slight decay at the base of one, provided the terminal bud is not infected.
(c) Less than half of the cotyledons covered with spots or darkened areas.

Epicotyl: Too small to be evaluated but the terminal bud should be clearly visible.

Infections: Slight infection by fungi, provided the essential seedling structures are well-developed.

Abnormal seedlings -

Root: No root or a stubby root, usually associated with a shortened hypocotyl.

Hypocotyl: (a) Much shortened, thickened or curled, usually associated with a stubby root.
(b) Watery hypocotyls, provided this is not caused by improper test conditions; usually associated with other abnormalities.
(c) Deep, unhealed cracks or grainy areas.

Cotyledons: (a) Decay at the point of attachment of both cotyledons, which may or may not involve the terminal bud.
(b) Decay at the point of attachment of one cotyledon, provided the terminal bud is also decayed.
(c) 50 percent or more of the area covered with spots or darkened areas.

Infections: Decayed roots or hypocotyls, provided the infection was not caused by improper test conditions.

Other Crucifers
Garden cress; Water cress (Manual p. 124)

CUCURBITACEAE - Cucurbit family (Manual pp. 124-125, fig. 34) 2/

Watermelon; Cantaloup; Pumpkin; Citron
Squash (Neg. No. 19537-19538); Cucumber (Neg. Nos. 19535-19536) 3/

Normal seedlings -

Root: (a) A strong and vigorous primary root, with or without secondary roots.
(b) A stubby primary root with at least two strong and vigorous secondary roots.

Hypocotyl: Long, or short but well-developed.

Cotyledons: Two, free from decay or other injury.

Epicotyl: Usually too small to evaluate except in sand or soil tests, but must have intact terminal bud.
Infections: Slight infection by fungi, provided the essential seedling structures are well-developed.

Abnormal seedlings -

Root: (a) No primary root.
(b) A stubby primary root with no secondary roots.
(c) A stubby primary root with weak secondary roots, usually associated with a short hypocotyl.

Hypocotyl: Malformed, usually shortened or much thickened; if due to chemical treatment, count as abnormal if the injury is still apparent in a soil test. (Manual p. 98)

Cotyledons: One or both missing.

Infections: Decayed cotyledons or other structures, provided this was not caused by improper test conditions.

GRAMINEAE - Grass family (Manual pp. 126-130) 2/

CEREALS (Manual pp. 131, 139; figs. 35-37)

Barley; Oats (Neg. Nos. 2407, 2527; frost injury, 19545, 19546); Rye (Neg. Nos. 2403, 2406, 2529; Wheat (Neg. Nos. 25-7, 2521) 3/

Normal seedlings -

Root: One tap root or 2 or 3 seminal roots.

Plumule: (a) Well-developed leaf, green in color, and long enough to extend about half way up in the sheath or higher.
(b) Spiral twisting or bending, provided it is not the result of frost damage. (Manual figs. 35 and 36.)

Infections: Slight infection by fungi, provided the essential seedling structures are well-developed.

Abnormal seedlings -

Root: (a) Only one or two short and weak seminal roots, which are usually accompanied by weakened plumules and decayed grains, no primary root.
(b) A short, thickened root, often the result of overtreatment of seed with chemicals. Count as abnormal if condition persists in soil test.

Plumule: (a) No green leaf, only the colorless coleoptile.
(b) The leaf extending less than half way up in the coleoptile.
(c) A weak, watery plumule, usually accompanied by weak root development and a decayed grain.
(d) Longitudinally split leaf, with or without splitting of the coleoptile.
(e) Leaf emerging through a split near the base of the coleoptile. (See frosted oats.)
(f) A thickened and shortened plumule, often the result of over-treatment of seed with chemicals. (Manual p. 98) Count as abnormal if the condition persists in the soil test.
(g) Weak plumules, with decay at the point of attachment to the grain.
(h) Frost damage, characterized by grainy coleoptiles and shredded or spirally twisted plumules. (Manual p. 99; fig. 35.) In soil tests, some of the longest of the spirally twisted seedlings will appear fairly strong but most of them break off just above the attachment of the plumule to the grain.

Infections: Infection by fungi, associated with weak plumule and root.

GRAMINEAE - Grass family (Con.) (Manual pp. 126-130) 2/

Sorghum (Neg. Nos. 2415, 2416); Sudan grass (Neg. Nos. 2450, 2451) 3/
Manual p. 141; figs. 41, 42)

Normal seedlings -

Root: One primary root, usually with well-developed secondary roots and root hairs if left for final counts; ~~xxxxxxxxxxxx~~ roots may show some red coloration due to natural pigments.

Plumule: Well-developed green leaf, usually emerged from the coleoptile by the end of the test (note the elongation of the first internode); coleoptile may show some red coloration due to natural pigments.

Infections: Slight infection by fungi, provided the essential seedling structures are well-developed.

Abnormal seedlings -

Root: No root or a weak and short primary root, which is often associated with decay of the grain.

Plumule: (a) No green leaf, only the colorless coleoptile.
(b) The leaf extending less than half way up in the coleoptile.
(c) Plumule weak and pale, usually associated with moldy seed.
(d) Shredded and longitudinally split leaves, with or without splitting of the coleoptile.
(e) Weak plumules, with decay at the point of attachment to the grain.
(f) Decayed plumules, provided the decay is not the result of improper test conditions.

Infections: Infection by fungi, associated with weak plumule and root development.

GRAMINEAE - Grass family (Con.) Manual pp. 126-130) 2/

Corn
(Manual p. 141; figs. 39-40) (Neg. Nos. 2510, 2511) 3/

Normal seedlings -

Root: (a) A strong primary root, usually with secondary roots present.
(b) No primary root but with at least 2 vigorous secondary roots.

Plumule: (a) A well-developed green foliage leaf, usually emerged from the coleoptile by the end of the test period.
(b) Twisted or curled plumules bound by the tough seed coat, provided the plumule is not decayed.

Infections: Slight infection by fungi, provided the essential seedling structures are well-developed.

Abnormal seedlings -

Root: (a) No primary or secondary roots.
(b) No primary root, but with short and weak secondary roots.

Plumule: (a) No foliage leaf, only the colorless coleoptile.
(b) A shortened foliage leaf, extending less than half way up in the coleoptile.
(c) A weak, pale plumule, usually associated with moldy seeds.
(d) A short, thickened plumule, often the result of overtreatment of seed with chemicals.
(e) Foliage leaf entirely white (albino). The seedling will not develop into a plant because of lack of chlorophyll.
(f) Shredded or longitudinally split leaves, with or without splitting of the coleoptile.
(g) Decayed plumules, provided the decay is not the result of improper test conditions. The plumules usually appear weak and show decay near the point of attachment to the grain.

Infections: Infection by fungi, associated with weak plumule and root.

GRAMINEAE - Grass family (Con.) (Manual p. 126-130) 2/

Rice

(Manual pp. 130 and 139, fig. 38) (Neg. No. 19549, 19550)

Normal seedlings -

Root: A long primary root, usually with numerous secondary roots; several permanent roots arising from the first node (crown roots) should be present if the seedling is not removed until the end of the test.

Plumule: Well-developed green foliage leaf, usually emerged from the coleoptile at time of evaluation.

Infections: Slight infection by fungi, provided the essential seedling structures are well-developed.

Abnormal seedlings -

Root: (a) None.
(b) A weak primary root with little or no secondary root development.

Plumule: (a) No foliage leaf, only the colorless coleoptile.
(b) A weak, and sometimes watery plumule, usually associated with decay of the grain.
(c) A short foliage leaf, extending less than half way up in the coleoptile.
(d) Shredded or longitudinally split foliage leaf, with or without splitting of the coleoptile.
(e) Decayed plumule, provided the decay is not the result of improper test conditions; the plumule is usually weak and shows decay at the point of attachment to the grain.

Infections: Infection by fungi, associated with weak plumule and root.

GRAMINEAE - Grass family (Con.) (Manual p. 126-130) 2/

Small-seeded Grasses
(Manual p. 130, 142; fig. 43) 3/

Normal seedlings -

Root: (a) A vigorous primary root, usually with root hairs.
(b) Spirally coiled roots held within the tightly enveloping glumes, as in certain samples of Bermuda grass, Cynodon dactylon.
(c) Poor root development resulting from injury caused by the use of a potassium nitrate solution. If many roots are affected, a retest should be made on top of soil in closed petri dishes. See Manual, p. 102.

Plumule: A well-developed green leaf, which has usually emerged from the coleoptile by the end of the test period.

Infections: Slight infection by fungi, provided the essential seedling structures are well developed.

Abnormal seedlings -

Root: (a) No root, but examine for coiled root described under (b) above; if many rootless seedlings are present it may indicate improper test conditions.
(b) A weak, short or stubby, root/often watery and associated with a decayed seed.

Plumule: (a) No foliage leaf, only the colorless coleoptile which is often short and thick.
(b) A shortened foliage leaf, extending less than half way up in the coleoptile.
(c) A weak plumule, usually pale and watery.
(d) A shredded or longitudinally split foliage leaf, with or without splitting of the coleoptile.
(e) Lower portion of foliage leaf emerging through a split near the base of the coleoptile.
(f) Decayed plumule, provided the decay is not the result of improper test conditions; plumule usually appears weak and shows decay near the point of attachment to the grain.

Infections: Infection by fungi, associated with weak plumule and root.

LEGUMINOSAE - Legume or pea family (Manual pp. 142-146) 2/

The Hypogeous Growth-habit Group

Peas; Vetch; Velvet bean; Broadbean; Runner bean; Chickpea; Roughpea
(Manual p. 157; figs. 48, 49) 3/

Normal seedlings -

Root: A strong taproot or a set of secondary roots sufficient to anchor the seedling when grown in soil or sand.

Hypocotyl: Not evident in hypogeous-type seedlings.

Cotyledons: Two, not detached from the seedling.

Epicotyl: (a) A well-developed stem with no deep cracks or lesions.
(b) The stem with at least one true leaf and an intact primary bud.
(c) Two shoots, provided at least one of them has a normal epicotyl and root and appears vigorous.

Infections: Slight infection by fungi, provided the essential seedling structures are well-developed.

Abnormal seedlings -

Root: No tap root or well-developed secondary roots.

Hypocotyl: Not evident in hypogeous-type seedlings.

Cotyledons: One or both broken away from the seedling.

Epicotyl: (a) No stem, or a stem without a terminal bud.
(b) A malformed stem, which may be curled, shortened or thickened, or have deep open cracks.
(c) Two shoots, both of which appear weak, often partially broken away from the cotyledons.
(d) Decayed seedling caused by the spread of decay from the cotyledons.

Infections: Infection by fungi, usually associated with weak root and stem development.

LEGUMINOSAE - Legume or pea family (Manual pp. 142-146) 2/

BEANS (Epigeous growth-habit)

Garden; Field; Lima; Adzuki; Mung; Asparagus bean
(Manual pp. 153, 156-157; figs. 44-47) 3/

Normal seedlings -

Root: A strong taproot or a set of secondary roots and sufficient to anchor the seedling when grown in soil or sand.

Hypocotyl: (a) Long, or short but sturdy, with no deep cracks or lesions.
(b) Healed breaks, sometimes referred to as "knees," provided the seedling is vigorous. Manual fig. 45.
(c) Spirally twisted and curled hypocotyl and root, held within the tough seed coat, causing delayed emergence, but otherwise normal.

Cotyledons: One or both may be missing, provided the epicotyl is intact.

Epicotyl: (a) One, and preferably 2 primary leaves, with intact terminal bud.
(b) Partial or total decay of the epicotyl, provided the hypocotyl and root are well-developed. The epicotyl on such seedlings usually does not decay when grown in a drier atmosphere and sunlight where the cotyledons open out naturally. However, if there are many such seedlings a retest should be made and the seedlings evaluated cautiously.

Infections: Slight infection by fungi, provided the essential seedling structures are well-developed.

Abnormal seedlings -

Root: (a) No tap root or a well-developed set of secondary roots.
(b) A split in the root extending into the hypocotyl.

Hypocotyl: (a) With deep, open cracks.
(b) Malformed, may appear curled, shortened and thickened.

Cotyledons: Present but epicotyl lacking.

Epicotyl: (a) No primary leaves or terminal bud (baldhead). Fig. 4, a.
(b) No primary leaves but with a terminal bud (partial baldhead). Fig. 4, b.
(c) No primary leaves, but terminal bud present and axillary buds in one or both axils of the cotyledons (partial baldhead). Fig. 4, c.
(d) Primary leaves very small and pale.

Fig. 4. Bean seedlings showing types of baldheads.

LEGUMINOSAE - Legume or pea family (Manual pp. 142-146) 2/

LARGE-SEEDED LEGUMES (Epigeous growth-habit)

Cowpeas; Soybeans; Lupines; Peanuts
(Manual p. 158; figs. 50-52) 3/

Normal seedlings -

Root: A strong taproot or a set of secondary roots sufficient to anchor the seedling when grown in soil or sand.

Hypocotyl: Long, or short and well-developed, with no deep open cracks.

Cotyledons: Present or absent, provided the epicotyl is present.

Epicotyl: (a) At least one foliage leaf and an intact terminal bud. Epicotyl injury due to weevil infestation is especially common in cowpeas and lupines.
(b) Partial or total decay of the epicotyl, provided the hypocotyl and root are well-developed. The epicotyl on such seedlings usually does not decay when grown in a drier atmosphere and sunlight where the cotyledons open out naturally. However, if there are many such seedlings a retest should be made and the seedlings evaluated cautiously.

Infections: Slight infection by fungi, provided the essential seedlings structures are well-developed.

Abnormal seedlings -

Root: (a) No taproot or well-developed secondary roots.
(b) A split in the root extending into the hypocotyl.

Hypocotyl: (a) With deep, open cracks.
(b) Malformed, may appear curled, shortened or thickened.

Cotyledons: One or both present but the epicotyl lacking.

Epicotyl: (a) No primary leaves or terminal bud. See baldheads, Fig. 4.
(b) Primary leaves present but no terminal bud.

Infections: Decayed epicotyl, provided the decay has spread from the decayed cotyledons, usually associated with weak hypocotyl and root development. See also Normal seedlings, Epicotyl (b), above.

LEGUMINOSAE - Legume or pea family (Manual pp. 142-146) 2/

SMALL-SEEDED LEGUMES (Epigeous growth-habit)

Alfalfa; Black medic; Clovers; Crotalaria; Kudzu; Lespedeza; Sesbania; Trefoil (Manual pp. 159-160; figs. 53-56) 3/

Normal seedlings -

Root: (a) A long, slender taproot, usually with root hairs.
(b) Short or stubby roots on blotter tests of sweetclover.
(c) Roots slightly stubby from being held back by the attached seed coat.
(d) Slight splits on the roots, provided they do not extend into the central conducting tissues.

Hypocotyl: (a) Long, well-developed, may have slight cracks provided they do not extend into the central conducting tissues.
(b) Healed-over cracks or lesions (commonly found in sweetclover).

Cotyledons: At least one, provided the terminal bud is intact.

Epicotyl: Not sufficiently developed for evaluation except in soil tests.

Infections: Slight infection by fungi, provided the essential seedling structures are well developed.

Abnormal seedlings -

Root: (a) Stubby roots, usually associated with shortened hypocotyls.
(b) Deep cracks extending up into the hypocotyl.

Hypocotyl: (a) Deep cracks or splits which extend into the central conducting tissues.
(b) Weak and watery seedlings, provided they are not the result of excess moisture in the substratum.

Cotyledons: (a) Both cotyledons broken off.
(b) One cotyledon and no terminal bud.
(c) Decayed cotyledons, provided the decay did not spread to the seedling from an adjacent seed or was not the result of improper test conditions.

Infections: Infections by fungi, usually associated with weak hypocotyl and root.

LILIACEAE - Lily family (Manual pp. 160-162) 2/

Onion; Leek (Epigeous growth-habit)
(Manual p. 161; fig. 57) (Neg. Nos. 1962, 2469)

Normal seedlings -

Root: A long, slender root, with or without root hairs, and a slight thickening at the base of the cotyledon.

Hypocotyl: Not distinguishable from the upper part of the root without anatomical sections.

Cotyledon: Long, green, leaf-like, with a well-developed bend or "knee" about midway.

Infections: Slight infection by fungi, provided the essential seedling structures are well-developed.

Abnormal seedlings -

Root: No root, a short and weak root, or a stubby root.

Hypocotyl: Not distinguishable from the upper part of the root without anatomical sections.

Cotyledons: (a) Very short, usually associated with poor root development.
(b) Cotyledon without a definite bend or "knee".
(c) Decayed cotyledon, provided the decay is not the result of improper test conditions.
(d) Weak and watery, usually associated with a weak root and other abnormalities.

Infections: Infections by fungi, usually associated with weak roots and cotyledons.

Asparagus (Hypogeous growth-habit)
(Manual pp. 161-162) 2/

LINACEAE - Flax family

Flax (Epigeous growth-habit)
(Manual pp. 162-163, fig. 58) (Neg. No. 2005) 2/

Normal seedlings -

Root: (a) Long, slender primary root, usually with root hairs.
(b) A short and stubby primary root, with strong secondary roots.

Hypocotyl: Long and vigorous, with no deep cracks or lesions.

Cotyledon: (a) At least one, provided the terminal bud is intact.
(b) Variously broken or cracked cotyledons, provided the other seedling structures are well-developed.

Infections: Slight infection by fungi, provided the essential seedling structures are well-developed.

Abnormal seedlings -

Root: No primary root or strong secondary roots.

Hypocotyl: (a) Deep cracks or lesions extending into the central conducting tissues.
(b) Malformed, appearing twisted, thickened or shortened.

Cotyledon: (a) Both cotyledons broken off.
(b) One cotyledon broken off and the terminal bud damaged.

Infections: Decayed cotyledons or other essential structures, provided the decay is not the result of improper test conditions.

MALVACEAE - Mallow family (Manual pp. 164-167) 2/

Cotton: Okra (Epigeous growth-habit)
(Manual pp. 166-167; figs. 59, 60) (Neg. Nos. 19533, 19543) 3/

Normal seedlings -

Root: (a) Long, slender primary root, usually with root hairs.
(b) No primary root but strong secondary roots.
(c) Yellowish areas on roots of cotton. See Hypocotyl (b).

Hypocotyl: (a) Long and well-developed, with no deep cracks or grainy areas.
(b) Yellowish areas on hypocotyls of cotton, provided the cotyledon is free of infection. The seed coat must be peeled back on young seedlings to determine this.

Cotyledon: Two or only one, provided the growing point is intact.

Infection: Slight infection by fungi, provided the essential seedling structures are well-developed.

Abnormal seedlings -

Root: No root, or very short and stubby root, without strong secondary root development.

Hypocotyl: (a) Thickened, resulting from chemical treatment of seed, such as occurs on delinted cotton; usually associated with stubby roots.
(b) Malformed, which may be curled, shortened or thickened.
(c) Deep cracks or grainy areas.

Cotyledon: One or both present, but no terminal bud.

Infections: Decayed cotyledons and hypocotyls, provided the decay did not spread from another seed or was not the result of improper test conditions.